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Status and Trends of Prey Fish Populations in Lake Superior, 2009[1]

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Abstract

The Great Lakes Science Center has conducted annual daytime bottom trawl surveys of the Lake Superior nearshore (15-80 m bathymetric depth zone) each spring since 1978 to provide long-term trends of relative abundance and biomass of the fish community. Between 27April and 19 June 2009, 63 stations distributed around the perimeter of the lake were sampled with 12-m Yankee bottom trawls towed cross-contour. The lakewide mean relative biomass estimate for the entire fish community was 1.22 kg/ha which is the lowest in the 32-year survey history. Biomass across jurisdictions was relatively even; levels in Canada East, Canada West, Michigan, Minnesota and Wisconsin waters were 1.99, 1.29, 1.12, 1.12, and 0.62 kg/ha, respectively. Dominant species in the catch, in order of relative abundance, were rainbow smelt, lean lake trout, siscowet lake trout, bloater, and lake whitefish. Compared to 2008 levels, rainbow smelt, lake whitefish, bloater and cisco biomass decreased while lean lake trout biomass increased. Year-class strengths for the 2008 cisco and bloater cohorts were well below average. A decline in smelt year class strength reversed a trend of increasing strength from 2003-2008. The 2008 cisco age structure was dominated by age-6 and older fish, which accounted for 79% of the ciscoes captured..

Densities of all sizes of hatchery lake trout continued a pattern of decline observed since 1993-1996. Densities of small- (< 226 mm TL) and intermediate-size (226-400 mm TL) wild (lean) lake trout continued a decreasing trend observed since 1996-1998. Density of large (> 400 mm TL) lean lake trout has been relatively stable since 1986. Siscowet have shown a pattern of variable but increasing density since 1980. For 2009, densities of small- and intermediate-size siscowet decreased while densities of large siscowet remained unchanged. In the 2009 survey, proportions of total lake trout density that were hatchery, lean and siscowet were 5, 61, and 34%, respectively.

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Introduction

The Great Lakes Science Center's Lake Superior Biological Station conducts an annual daytime bottom trawl survey each spring in Lake Superior. The survey is intended to provide long-term trends of relative abundance and biomass of the fish community in nearshore waters. Beginning in 1978, the survey included 43-53 stations in United States (U.S.). Canadian waters were added in 1989 raising the sampling effort to 76-86 stations. In 2005, the number of stations sampled lake-wide was reduced to 58 after it was found that this smaller sample yielded similar estimates of relative biomass of major species (Stockwell et al. 2006a). In this report, we update the time series with data collected in 2009.

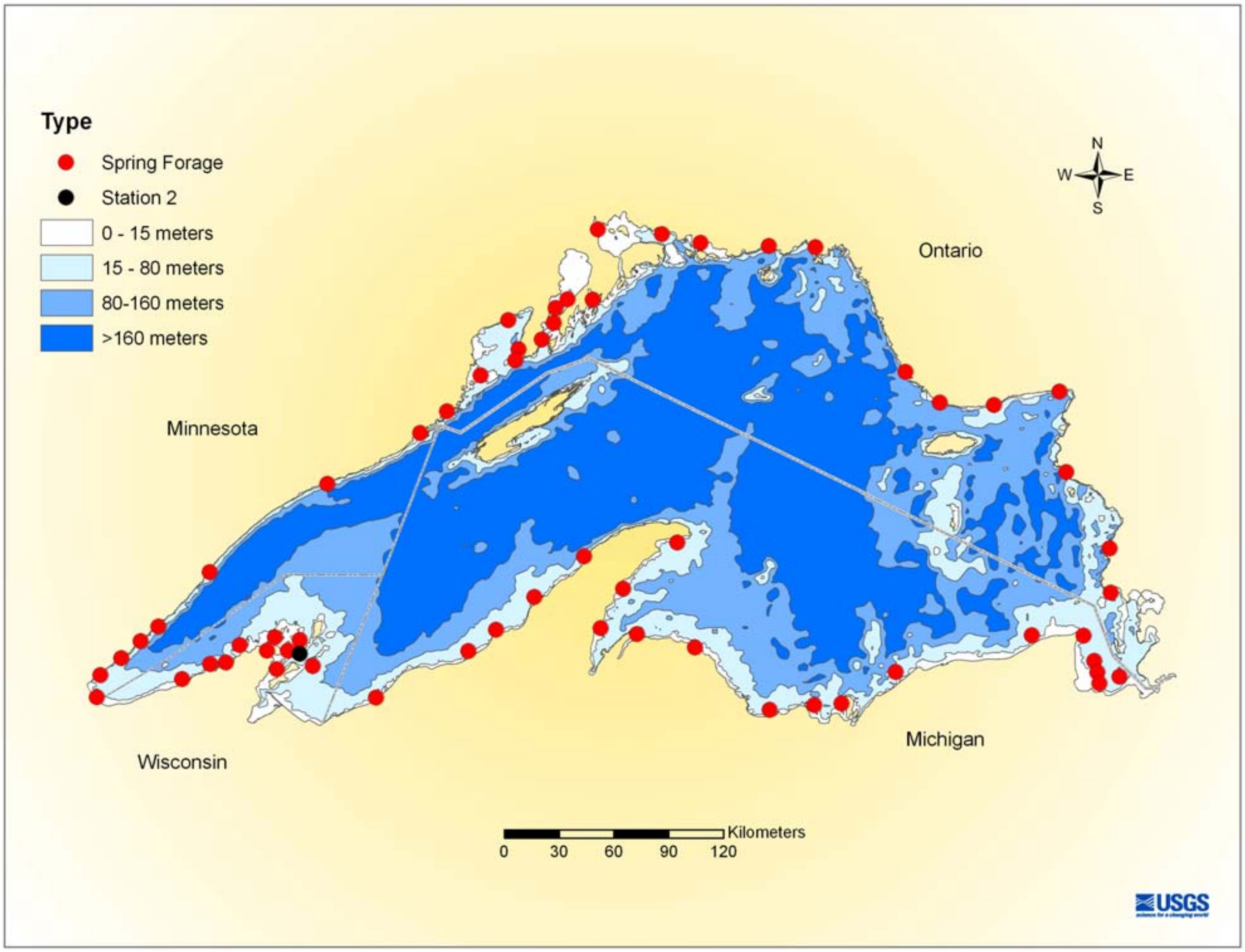


Figure 1. *Locations of 63 stations (red and black dots) sampled during the 2009 annual spring bottom trawl survey of Lake Superior.*

Methods

Spring Survey

A total of 63 stations distributed around the perimeter of Lake Superior were sampled with bottom trawls during daylight hours between 27 April and 19 June 2009 (Fig. 1). We were able to sample fish at all 58 stations that were identified in 2005 as adequate for estimating relative biomass of principal prey species in Lake Superior (Stockwell et al. 2006a). These 58 stations represented a subset of 85 stations sampled annually during 1978-2004. Five stations were added in 2009 because of favorable logistics.

A single sample was taken at each station with a 12-m Yankee bottom trawl towed cross-contour. The median start and end depths for bottom trawl tows were 16 m (range 12-34 m, interquartile range 15-20 m) and

54 m (range 19-130 m, interquartile range 45-68 m), respectively. Median trawl tow duration was 22 minutes (range 7-61 minutes, interquartile range 15-34 minutes). Fish were sorted by species, counted, and weighed in aggregate to the nearest gram. Relative density (fish/ha) and biomass (kg/ha) were estimated by dividing sample counts and aggregate weights by the area of the bottom swept by each trawl (ha). These estimates were then modified by the station-specific weighting given in Stockwell et al. (2006a) to retain comparability with unweighted data prior to 2005.

For principal prey species (cisco *Coregonus artedi*, bloater *C. hoyi*, rainbow smelt *Osmerus mordax*, lake whitefish *C. clupeaformis*), year-class strength was estimated as the relative density (fish/ha) of age-1 fish, the first age-class that recruits to the bottom trawl. Densities of age-1 fish were estimated from densities of rainbow smelt < 100 mm, lake whitefish < 160 mm, cisco < 140 mm, and bloater < 130 mm. To be consistent with past reports and to more easily identify the year in which a cohort was produced, year-class strength is plotted against the year in which the cohort was produced (year sampled minus 1). Standard errors (SE) were calculated as $SD/\sqrt{n}$, where SD = the sample standard deviation and n = number of observations. For sample years after 2004 when weighted means were calculated, SE was calculated from the unweighted data. The SE was standardized by the mean to generate relative standard error (RSE = SE/mean*100).

To determine the age structure of Lake Superior cisco in 2009, we used a length-age key to estimate relative density of each age-class as a function of length. To stratify sampling of fish for age determination, we divided Lake Superior into nine regions, and took structures from a maximum of 10 ciscoes per 10-mm length bin over a 50-400 mm TL range per region. Ages for all cisco were estimated from scales by a single trained reader. Age estimates from otoliths were not available in 2009. Because we were limited to application of scale age data in 2009, we recognized that the resulting estimate of age composition of cisco would likely be inaccurate as suggested by Yule et al. (2008). To address this deficiency, we developed a statistical age key based on scales and otoliths collected in 2000-2006, similar to the approach used by Gorman (2007) for rainbow smelt and Gorman et al. (2008) for cisco. Because scales become less reliable as aging structures as coregonids mature (Aass 1972; Mills and Beamish 1980; Yule et al. 2008), we used scales for fish < 250 mm and otoliths for fish ≥ 250 mm. Age estimates from otoliths were acquired by the crack and burn method (Schreiner and Schram 2001). Using this 2000-2006 age data, we generated size-at-age distributions for age classes 1 to 9 and ≥10 years. A default age key based on a composite catch curve and size-at-age distributions was then modified by weighting age classes by the relative abundance of their age-1 abundance. This weighted statistical age key was then applied to 2009 length-frequency distribution to estimate size-age specific density distributions.

Because our bottom trawls capture a broad spectrum of lake trout *Salvelinus namaycush* sizes and life stages, biomass estimates are sensitive to variable capture of large adult fish (Stockwell et al. 2007). Therefore, as in previous reports (Gorman et al. 2008, 2009), we summarized our lake trout data as density by size bins: small, < 226 mm (≤ ca., age-3), intermediate, 226-400 mm (ca., age 4-8), and large, > 400 mm (>ca., age-8). To dampen inter-annual variation in our density estimates, we used 2-year moving averages for hatchery and wild (lean) lake trout, and 3-year moving averages for siscowet lake trout.

Results

A very large catch of fish was collected at Station 2 in Wisconsin waters of Lake Superior (Fig. 1). This catch contained 4,421 fish weighing 250 kg, which represented 25% of all fish caught and 69% of the total biomass in the spring survey. Most of the site 2 catch consisted of bloaters (52%) and shortjaw cisco (*C. zenithicus*) (23%). This one sample accounted for 66% of all cisco, 53% of all whitefish, 80% of all bloater, and 95% of all shortjaw cisco captured in spring 2009. Estimates of biomass for cisco, bloater, and shortjaw cisco at this site were 8 standard deviations greater than the lake-wide means, while lake whitefish was 6 standard deviations greater than their mean. Because this one sample had an extreme effect on lake-wide and regional estimates, we omitted this sample from subsequent results. Inclusion of data from Station 2 did not change any trends noted in this report, but by excluding it we feel our overall results more accurately represent lake-wide conditions.

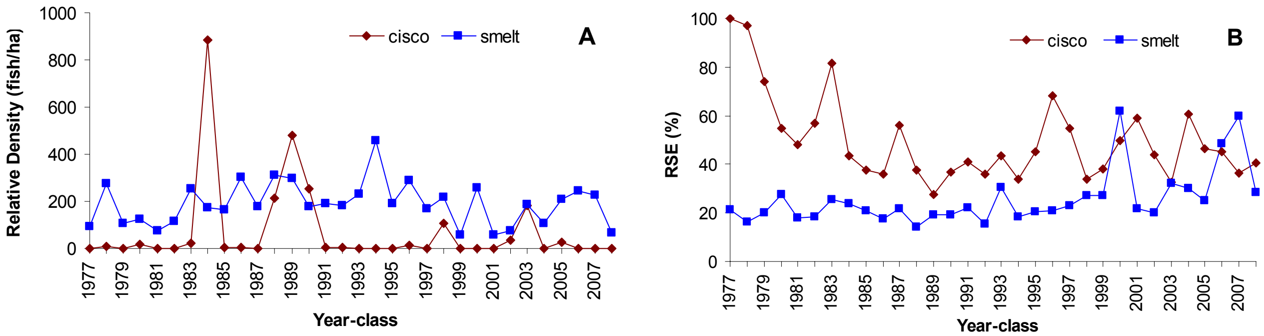


Figure 2. ***(A)*** *Year-class strength (number of age-1 fish/ha) for cisco and rainbow smelt for all nearshore sampling stations in Lake Superior for cohorts produced from 1977 to 2008. Only U.S. waters were sampled for the 1977-1988 year classes.* ***(B)*** *RSE (relative standard error) of year-class strengths.*

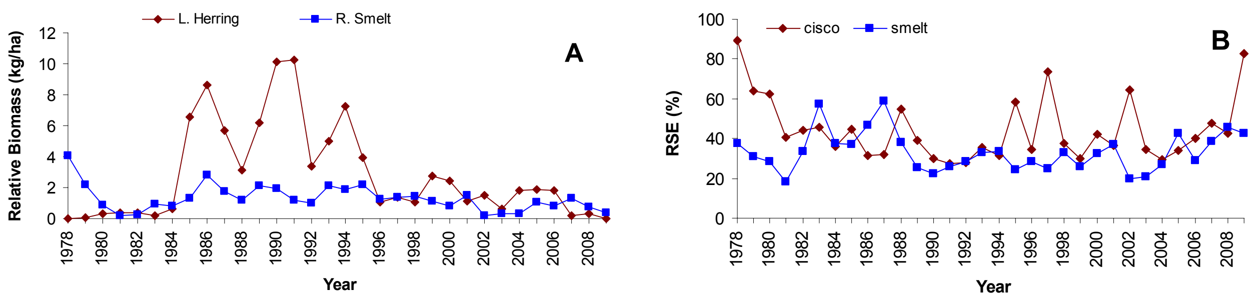


Figure 3. ***(A)*** *Mean relative biomass (kg/ha) of age-1 and older cisco and rainbow smelt for all nearshore sampling stations in Lake Superior, 1978-2009. Canadian waters were not sampled until 1989.* ***(B)*** *RSE (relative standard error) of mean biomass.*

Cisco

Year-class strength for the 2008 cisco cohort was estimated at 0.21 fish/ha, the seventh weakest year-class observed over the 32-year survey and one of six year classes of ≤ 1 fish/ha observed since 1999 (Fig. 2A). Year-class strength for the 2008 cohort in U.S. waters was 0.22 fish/ha and 0.18 fish/ha in Canadian waters. For comparison, the density of the strong 2003 year class was estimated at 182.25 fish/ha and moderate 2002 and 2005 year classes were estimated at 35.12 and 24.66 fish/ha, respectively (Fig. 2A). RSE estimated for the 2008 year class was 40%, which is lower than the series average of 50% (Fig. 2B) due to a large number of zero catches. The RSE for cisco year-class strength (Fig. 2B) exceeded the level of precision (no greater than ± 30% of the mean) recommended by Walters and Ludwig (1981) for stock-recruit data sets.

Mean relative biomass of age-1 and older cisco (0.02 kg/ha) in 2009 was lower than in 2008 (0.31 kg/ha) (Fig. 3A) and is the second lowest value in the 32-year record. The lowest relative biomass recorded was 0.01 kg/ha in 1978. The 2009 decrease continues the downward trend in biomass observed since 2004-2006 when biomass averaged ≥ 1.80 kg/ha and is below the long term 1978-2006 average of 2.90 kg/ha. The RSE of the 2008 cohort estimate was 83% in 2008, which was higher than the survey average of 45% and the highest since the beginning of the time series in 1978 when it was 89% (Fig. 3B).

Declines in relative cisco biomass were observed in all jurisdictions between 2008 and 2009 and continue the downward trend across all jurisdictions since 2004-2006 (Fig. 4). Relative biomass estimates as a percent of long-term means were low in W. Ontario (4.6%) and very low in Wisconsin (0.05%), Minnesota (0.39%), Michigan (0.11%) and E. Ontario (0.00%). This pattern is consistent with low cisco recruitment since 2003 and the tendency of adult ciscoes to utilize pelagic habitat not sampled by the bottom trawl (Stockwell et al. 2006b).

The mean relative density of all cisco showed a declining trend from 44.86 fish/ha in 2006 to 2.38 fish/ha in 2008 and 0.47 fish/ha in 2009. The 2009 cisco age structure was dominated by the 2003 year class (age-6) and older fish, with ≥ age-6 ciscoes collectively accounted for 79% of the mean relative density (Fig. 5). The 1998, 2002, 2003, 2005 cohorts and the most recent 2008 cohort accounted for 20, 27, 26, 4 and 14% of the mean relative density, respectively. Older cohorts (≥ age-7) represented 53% of the mean relative density (Fig. 5).

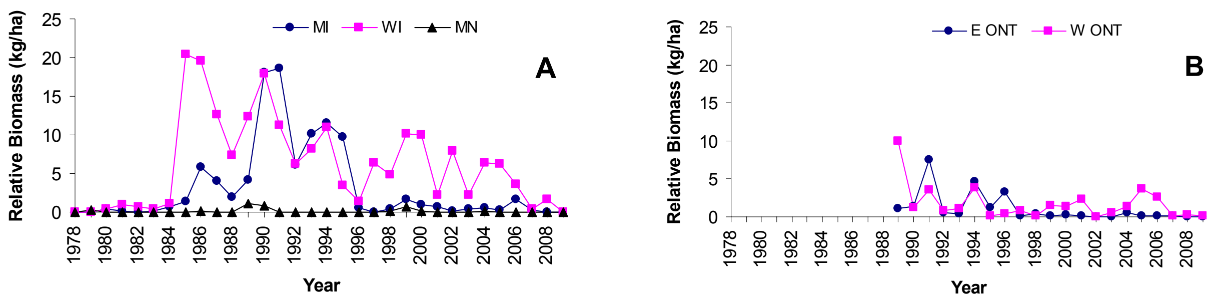


Figure 4. *Mean relative biomass (kg/ha) of age-1 and older cisco in nearshore waters of Lake Superior: (**A**) Michigan (MI), Wisconsin (WI), and Minnesota (MN), 1978-2009. (**B**) eastern and western Ontario, 1989-2009. Eastern and western Ontario waters are divided in the northeast corner of Lake Superior near Marathon, Ontario.*

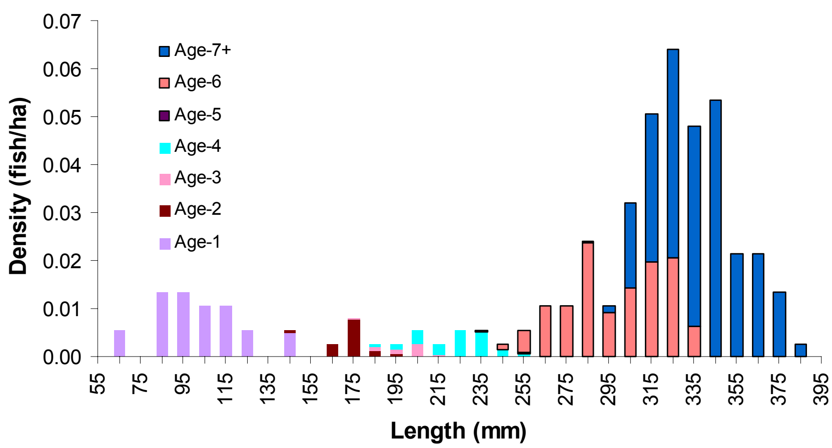


Figure 5. Estimated *age-length distribution of cisco caught at all nearshore sampling stations in Lake Superior in 2009.*

Rainbow Smelt

Year-class strength of rainbow smelt decreased from 226.26 fish/ha for the 2007 cohort to 65.3 fish/ha for the 2008 cohort (Fig. 2A). Year-class strength for the 2008 cohort was 38.4% of the average over the 32-yr survey period (189.8 fish/ha). RSE was relatively low (28.4%, Fig. 2B) and similar to the 32-yr average (26.0%), due to consistently low catches across all jurisdictions. The 2008 year-class was stronger in U.S. waters (96.0 fish/ha) compared to that in Canadian waters (16.9 fish/ha).

Mean relative biomass for age-1 and older rainbow smelt decreased 50% from 0.76 kg/ha in 2008 to 0.38 kg/ha in 2009 (Fig. 3A) and was 30% of the 31-year mean of 1.30 kg/ha. RSE in 2009 was 43%, which is within the 31 year survey range of 18-59% (Fig. 3B). Relative biomass of rainbow smelt declined in Wisconsin and Minnesota waters from 0.77 and 0.15 kg/ha in 2008 to 0.25 and 0.05 kg/ha in 2009, respectively (Fig. 6A). In contrast, biomass increased in Michigan waters from 0.34 to 0.71 kg/ha (Fig. 6A). Rainbow smelt biomass in W. Ontario waters decreased from 2.59 kg/ha in 2008 to 0.28 kg/ha in 2009 (Fig. 6B) while biomass in E. Ontario waters increased slightly from 0.17 kg/ha in 2008 to 0.24 kg/ha in 2009.

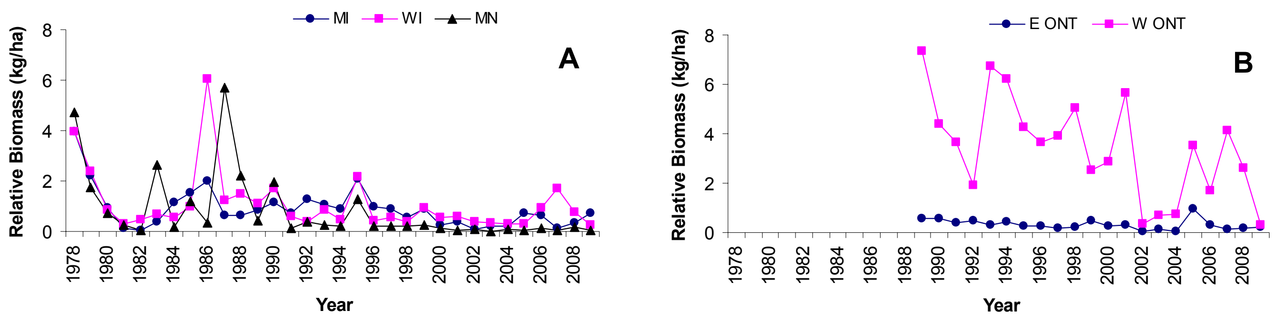


Figure 6. *Mean relative biomass (kg/ha) of age-1 and older rainbow smelt in nearshore waters of Lake Superior:* ***(A)*** *Michigan, Wisconsin, and Minnesota, 1978-2009.* ***(B)*** *eastern and western Ontario, 1989-2009.*

Bloater

Like the 2006 and 2007 cohorts, strength of the 2008 bloater year-class remained low (0.8 fish/ha) compared to the 2005 cohort (15.84 fish/ha; Fig. 7A) and well below the 31-year average of 10.8 fish/ha. Year-class strength was greater in U.S. waters (1.23 fish/ha) compared to Canadian waters (0.08 fish/ha). RSE of bloater yearling density in 2009 was 76%, which is outside the previous 31-year survey range of 22-65% (Fig. 7B).

Mean relative lake-wide biomass of age-1 and older bloater declined from 0.19 kg/ha in 2008 to 0.10 kg/ha in 2009 and contrasts with a recent peak of 1.36 kg/ha in 2006 (Fig. 8A). The 2009 relative biomass estimate was the lowest value observed since 1978 when it was 0.13 kg/ha. RSE for the 2008 cohort was 59%, which is within the 32-year survey range of 32-64% (Fig. 8B).

Between 2008 and 2009, bloater biomass declined in all U.S. jurisdictions, from 0.64 to 0.09 kg/ha in Michigan, 0.29 to 0.002 kg/ha in Wisconsin, and 0.01 to 0.001 kg/ha in Minnesota (Fig. 9A). Bloater biomass increased from 0.10 to 0.24 kg/ha in W. Ontario and from 0.02 to 0.10 kg/ha in E. Ontario (Fig. 9B).

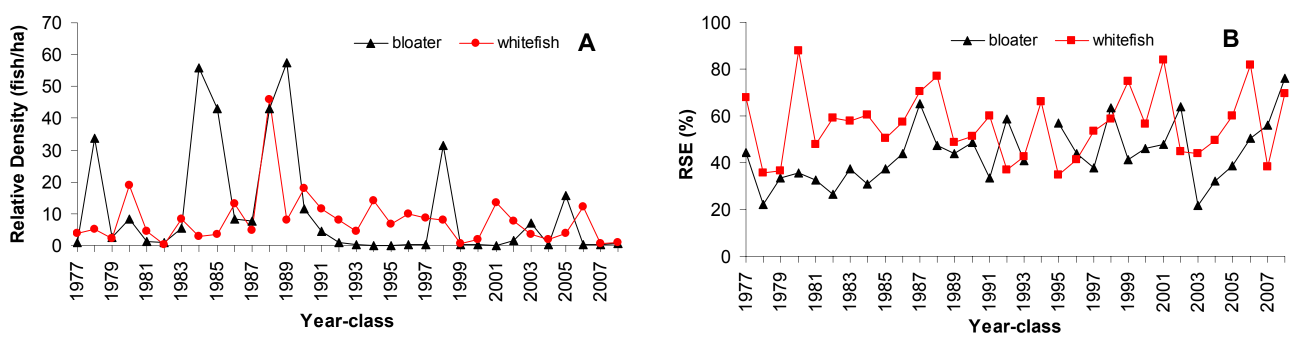


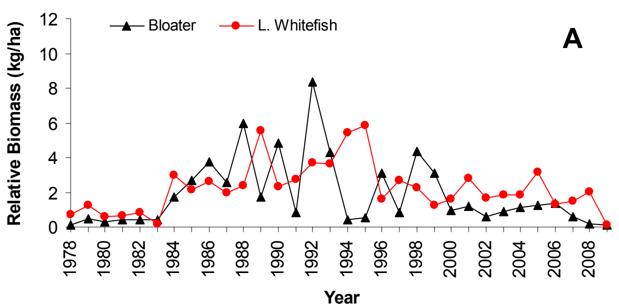
Figure 7. ***(A)*** *Year-class strength (number of age-1 fish/ha) for bloater and lake whitefish for all nearshore sampling stations in Lake Superior for cohorts produced from 1977 to 2008. Only U.S. waters were sampled for the 1977-1988 year-classes.* ***(B)*** *RSE (relative standard error) of year-class strengths.*

Lake Whitefish

Lake whitefish year-class strength increased slightly from 0.54 fish/ha for the 2007 cohort to 0.98 fish/ha for the 2008 cohort (Fig. 7A). RSE for lake whitefish year-class strength was 70%, which is within the 32-year survey range of 35-98% (Fig. 7B). The 2008 year-class was stronger in U.S. (1.58 fish/ha) than in Canadian waters (0.04 fish/ha). Average lake-wide year-class strength for lake whitefish over the 32-year survey period was 8.04 fish/ha.

Mean relative biomass for age-1 and older lake whitefish in all waters decreased from 2.04 kg/ha in 2008 to 0.09kg/ha in 2009 (Fig. 8A). The 2009 decrease represents a departure from a pattern of relatively stable biomass dating back to 1996. RSE for 2009 was 36%, which is well within the 32-year survey range of 29-66% (Fig. 8B).

Whitefish biomass decreased across all U.S. and Canadian jurisdictions. In Wisconsin, biomass decreased dramatically from 11.77 kg/ha in 2008 to 0.06 kg/ha in 2009, in Michigan from 1.05 to 0.04 kg/ha, and in Minnesota from 0.63 to 0.00 kg/ha (Fig. 10A). In Canadian waters, biomass decreased in W. Ontario from 0.38 to 0.18 kg/ha and E. Ontario from 0.26 to 0.17 kg/ha (Fig. 10B).



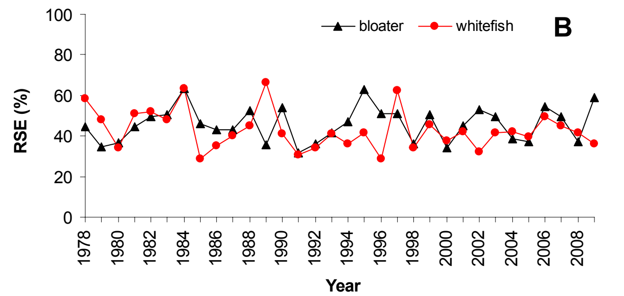
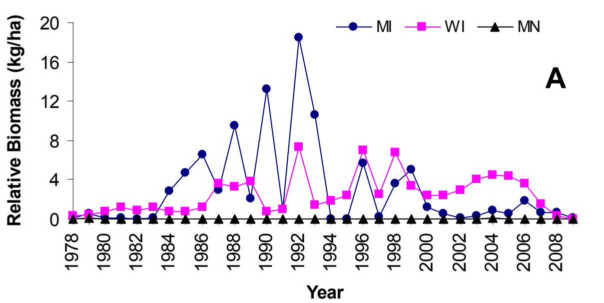


Figure 8. ***(A)*** *Mean relative biomass (kg/ha) of age-1 and older bloater and lake whitefish for all nearshore sampling stations in Lake Superior, 1978-2009. Canadian waters were not sampled until 1989.* ***(B)*** *RSE (relative standard error) of mean biomass.*



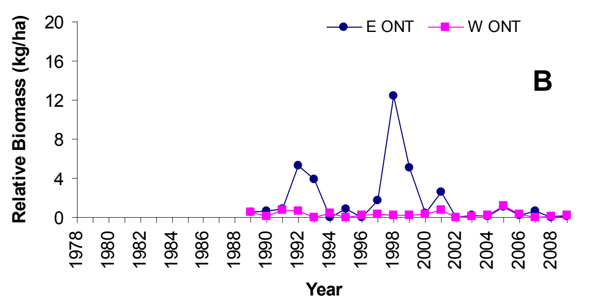


Figure 9. *Mean relative biomass (kg/ha) of age-1 and older bloater in nearshore waters of Lake Superior: (**A**) Michigan, Wisconsin, and Minnesota, 1978-2009. (**B**) eastern and western Ontario, 1989-2009.*

Other Species

Ninespine stickleback – Estimates of mean relative biomass for ninespine stickleback *Pungitius pungitius* decreased from 0.04 kg/ha in 2008 to 0.01 kg/ha in 2009 (Fig. 11A). Lake-wide mean relative biomass for all waters between 1978 and 1996 was 0.21 kg/ha.

Sculpins – Mean relative biomass for all three sculpin species combined (spoonhead *Cottus ricei*, slimy *C. cognatus*, and deepwater *Myoxocephalus thompsoni*) declined in 2009, paralleling the declining trend observed for ninespine sticklebacks since 1993 (Fig. 11A). In the recent 2006-2009 interval, annual estimates of sculpin relative biomass have remained low (0.03 kg/ha). Slimy sculpins were 50% of total sculpin biomass in 2009, followed by deepwater (44%) and spoonhead (6%) sculpins. Although deepwater sculpins dominated the assemblage in 2006-2008, slimy sculpins were the dominant species in the group from 1978-2005, with the exception of 1984 when deepwater sculpins represented 55% of the biomass. Slimy sculpins averaged >68% of the total sculpin biomass across all years, but represented a higher percentage from 1978 to 1983 (81%) compared to 1984 to 2001 (64%) and 2002-2009 (37%).

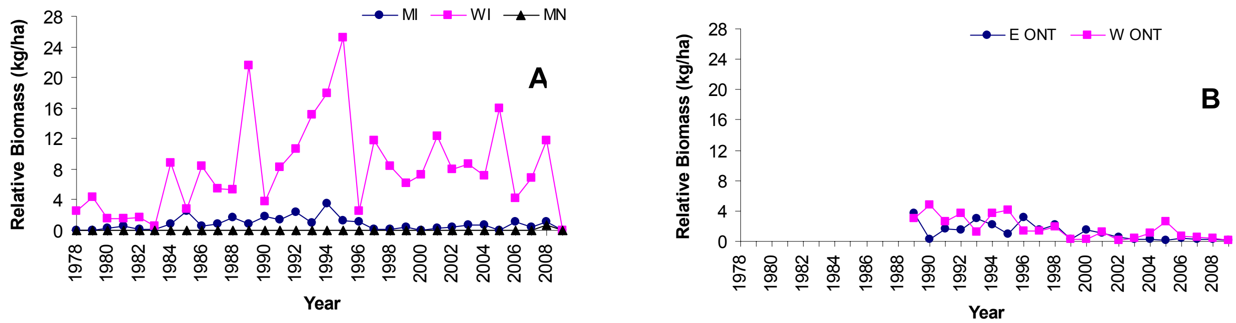


Figure 10. *Mean relative biomass (kg/ha) of age-1 and older lake whitefish in nearshore waters of Lake Superior: (**A**) Michigan, Wisconsin, and Minnesota, 1978-2009. (**B**) eastern and western Ontario, 1989-2009.*

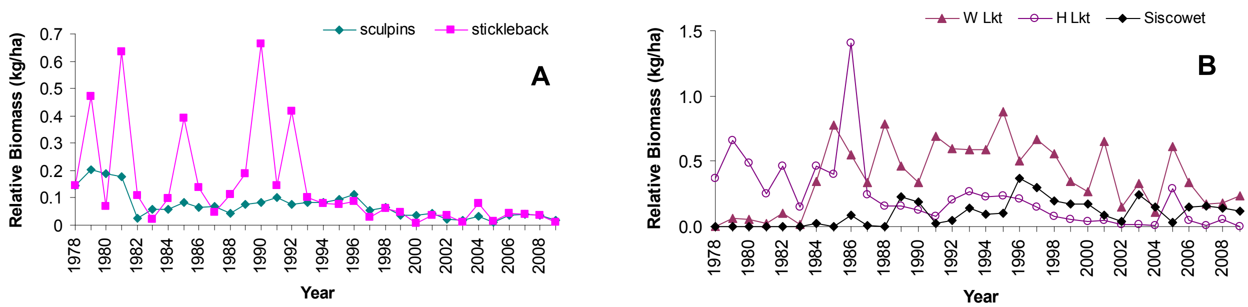


Figure 11. *Mean relative biomass (kg/ha) of age-1 and older (**A**) ninespine stickleback and sculpins (slimy, spoonhead, and deepwater combined), and (**B**) lake trout (wild-lean, hatchery, and siscowet) for all nearshore sampling stations in Lake Superior, 1978-2009. Canadian waters were not sampled until 1989.*

Lake Trout – Biomass of hatchery lake trout declined from 0.04 kg/ha in 2008 to near zero in 2009 (Fig. 11B). Biomass of wild lake trout increased from 0.15 kg/ha in 2008 to 0.24 kg/ha in 2009 while biomass of siscowet decreased from 0.17 to 0.12 kg/ha. Trends in biomass of wild, hatchery, and siscowet lake trout differed over the 32-year sampling record. Hatchery lake trout biomass declined after 1986 to very low levels by 1999 and remained low except for 2005 when we caught nine large fish in western Lake Superior (Fig. 11B). Before 1984, wild (lean) lake trout biomass was < 0.10 kg/ha (average 0.04 kg/ha). From 1984 through 2001 biomass increased, varying from 0.27 to 0.88 kg/ha (average 0.55 kg/ha), and afterwards shifted downward, varying from 0.11 to 0.65 kg/ha (average 0.27 kg/ha). Siscowet biomass began to increase after 1988 and afterwards fluctuated between 0.022 and 0.37 kg/ha (average 0.15 kg/ha).

Consistent with the decline beginning in 1993-1996, densities of small, intermediate and large hatchery lake trout declined to 0.01, 0.02, and 0.01 fish/ha in 2009, respectively (Fig. 12A). Densities of small and large wild lake trout remained similar in 2008 and 2009, thus pausing a decreasing trend that started in 1996-1998 (Fig. 12B). From 2008 to 2009, density of small wild lake trout declined slightly from 0.15 to 0.14 fish/ha; both values were the lowest in the 1978-2009 time series. Density of large wild lake trout increased from 0.10 kg/ha in 2008 to 0.14 kg/ha in 2009, reversing a decline from a recent peak of 0.43 kg/ha in 2006. Density of intermediate size lean trout decreased from 0.41 in 2008 to 0.24 fish/ha in 2009. Siscowet showed a pattern of variable but generally increasing density since1980 (Fig. 12C). From 2006 to 2008, densities of small and intermediate size siscowet lake trout increased from 0.10 to 0.12 and 0.08 to 0.15 fish/ha, respectively but in 2009 densities decreased to 0.07 and 0.12 fish/ha, respectively. Densities of large siscowet lake trout have fluctuated between 0.10 and 0.07 fish/ha since 2000. In 2009 the proportions of total lake trout density that were hatchery, wild and siscowet were 5, 61, and 34%, respectively.

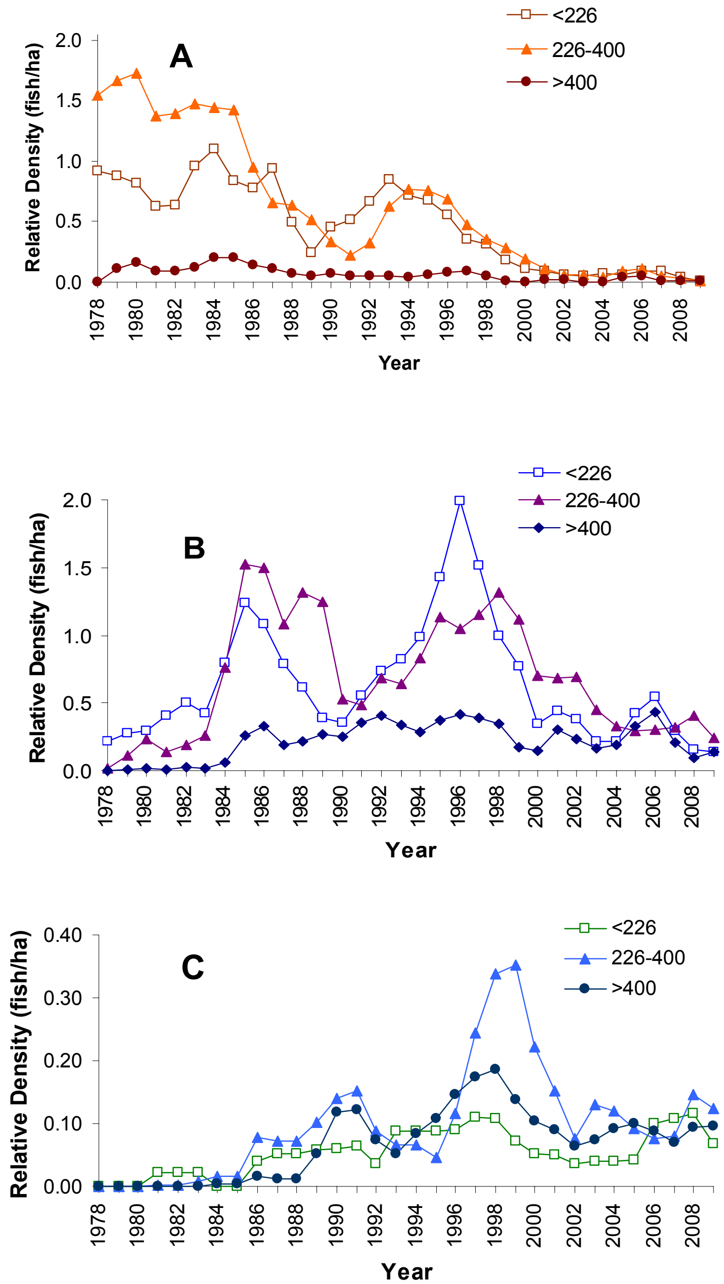


Figure 12. *Mean relative density (fish/ha) of age-1 and older lake trout for all nearshore sampling stations in Lake Superior, 1978-2009. Canadian waters were not sampled until 1989. Densities are shown for three length bins: <226 mm, 226-400 mm, and >400 mm TL. (**A**) hatchery lake trout, (**B**) wild (lean) lake trout, (**C**) siscowet lake trout.*

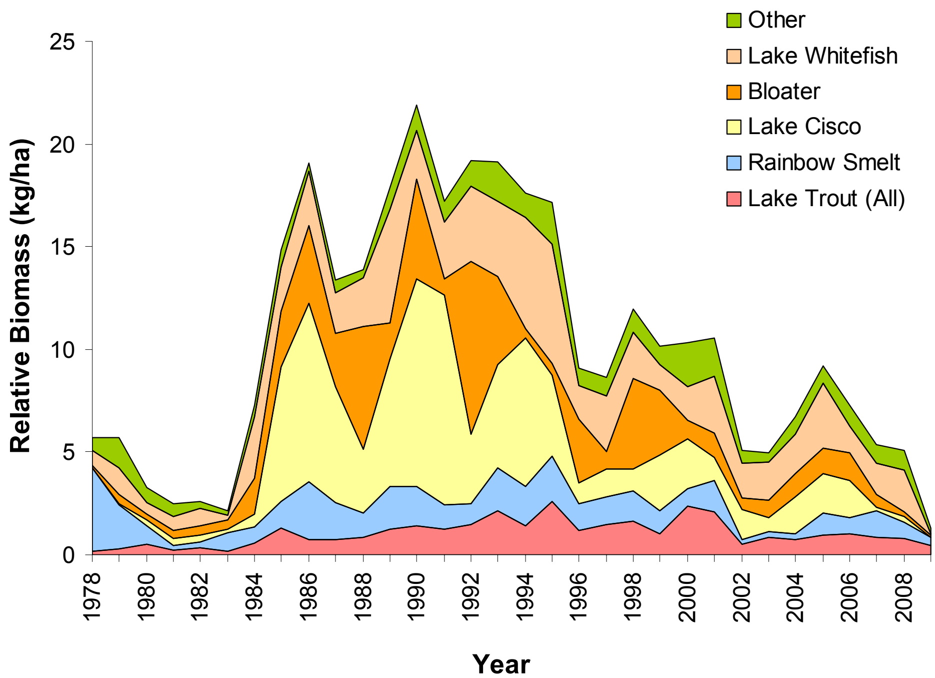


Figure 13. *Mean relative biomass (kg/ha) of the fish community caught in bottom trawls at all nearshore sampling stations in Lake Superior, 1978-2009. Canadian waters were not sampled until 1989.*

Lake Superior Fish Community

Since 2005, mean biomass of all fish species caught during the spring bottom trawl survey declined 87%; from 9.16 kg/ha in 2005 to 4.65 kg/ha in 2008 to 1.22 kg/ha in 2009 (Fig. 13). This decline followed two consecutive years of increased biomass; 34% increase from 2003 to 2004 and 45% increase from 2004 to 2005. Similarly, community biomass increased in 2000-2001 and then declined sharply in 2002-2003. Decreased biomass in 2006-2009 was a result of declines in estimated biomass of cisco, bloater, lake whitefish, rainbow smelt and lake trout. In 2009, principal species contributing to community biomass were rainbow smelt (31%), lean lake trout (19%), siscowet lake trout (10%), bloater (8%), and lake whitefish (7%). Cisco represented 2% of the community biomass, same as for shortjaw cisco, and behind pygmy whitefish (*Prosopium coulteri*) (6%), longnose sucker (*Catostomus catostomus*) (5%), burbot (*Lota lota*)(4%), and trout-perch (*Percopsis omiscomaycus*) (3%). This structure contrasts with the 2006 community when cisco represented the highest percentage of biomass for any species (26%), followed by bloater (20%), lake whitefish (20%), and rainbow smelt (12%).

Changes in estimated community biomass over the 32-year time series have been largely the result of changes in abundance of major prey species (Fig. 13). Rainbow smelt was the dominant prey fish prior to 1981 and afterwards dominance shifted to native prey species; cisco, bloater, and lake whitefish. Principal factors associated with changes in the community have been recovery of lake trout, increased mortality of rainbow smelt, sustained recruitment of lake whitefish, and variable recruitment of large year classes of cisco and bloater (Gorman and Hoff 2009). Annual variation in community biomass since 1984 has been driven by recruitment variation in cisco, bloater and lake whitefish. Recruitment of large year classes of cisco in 1984, 1988-1990, and 1998 resulted in subsequent increases in preyfish biomass (Fig. 13). Recruitment of the most recent large year class in 2003 yielded smaller and less sustained increases in biomass than previous years. During our November 2009 spawning cisco survey of western Lake Superior, we collected large numbers of age-0 ciscoes and deepwater ciscoes in midwater trawl samples. This catch suggests major year classes of ciscoes and deepwater ciscoes were produced in 2009. Surveys in 2010 will determine recruitment success. We suspect that the presence of recovered lake trout populations and attendant predation has dampened the more recent cisco recruitment events. In the future, we expect prey fish biomass to continue to fluctuate as a result of recruitment variation, however, predation mortality may lead to a continued decline in prey fish biomass. Declines in prey fish biomass in Lake Superior are consistent with recent declines in lean lake trout lipid content reported by Paterson et al. (2009).

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